Savannah River Site
Solid Waste Management Department
Consolidated Incinerator Facility
Operator Training Program

HEAT TRACE (U)

Study Guide

ZIOITX54

Revision 00

Training Manager / Date

Engineering / Date

Facility Manager / Date

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REVISION LOG

REV.	AFFECTED SECTION(S)	SUMMARY OF CHANGE
02	All	New Issue

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REFERENCES

1. DOE 5480.22, *Technical Safety Requirements*
2. DOE 5480.23, *SAR Nuclear Safety Analysis Report*
3. WSRC-SA-17, *Consolidated Incinerator Facility Safety Analysis Report*, Rev. 0
4. Drawing E-EH-H 7265, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule*
5. Drawing E-EH-H 7266, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule*
6. Drawing E-EH-H 7267, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule*
7. Drawing W830395, *SRS Bldg. 261-H Area 200H Single Line Diagram 480V Substation*
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12. Drawing W836269, *SRS Bldg. 261-H Area 200H Heat Trace Typical Wiring Diagrams*
13. Drawing W836270, *SRS Bldg. 261-H Area 200H Heat Trace Panel Schedules*
14. ZIOISX06, *Electrical System Design Description*
15. 261-SOP-HTTR-01, *Heat Tracing Procedure*, Rev. 0, IPC 95-116

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LEARNING OBJECTIVES

TERMINAL OBJECTIVE

1.00 Without references, **EXPLAIN** the significance of the Heat Trace System to Consolidated Incinerator Facility operations, including its importance to safety, and the impact on operations of a failure of the system.

ENABLING LEARNING OBJECTIVES

1.01 **STATE** the purpose of the Heat Trace System.

1.02 Briefly **DESCRIBE** how the Heat Trace System accomplishes its intended purpose.

1.03 **EXPLAIN** the consequences of a failure of the Heat Trace System to fulfill its intended purpose, including the effects on other systems or components, overall plant operation, and safety.

TERMINAL OBJECTIVE

2.00 Using system diagrams, **EVALUATE** potential problems which could interfere with normal Heat Trace System flowpaths to determine their significance on overall system operation and the corrective actions needed to return the system to normal.

ENABLING LEARNING OBJECTIVES

2.01 **DESCRIBE** the physical layout of the Heat Trace System components including the general location, and functional relationship for each of the following major components:

a. Disconnect Switches
b. Transformers
c. Thermostats
d. Heat Trace Panels
e. Heat Tracing

2.02 **DESCRIBE** the Heat Trace System arrangement to include a drawing showing the following system components and interfaces with other systems:

a. Disconnect Switches
b. Transformers
c. Heat Trace Panels
d. Motor Control Centers

2.03 Given a description of abnormal equipment status for the Heat Trace System, **EXPLAIN** the significance of the condition on system operation.

TERMINAL OBJECTIVE

3.00 Given values of Heat Trace System operation parameters, **EVALUATE** potential problems that could effect the normal functioning of the system or its components to determine the significance of the existing condition and the actions required to return the system to normal operation.

ENABLING LEARNING OBJECTIVES

3.01 **DESCRIBE** the following major components of the Heat Trace System including their functions, principles of operation, and basic construction:

a. Disconnect Switches
b. Transformers
c. Thermostats
d. Heat Trace Panels
e. Heat Tracing

3.02 **STATE** the operational limitations for the following Heat Trace System major components:

a. Disconnect Switches
b. Transformers

3.03 Given values for key performance indicators, **DETERMINE** if the Heat Trace System components are functioning as expected.

3.04 **DESCRIBE** the following Heat Trace System instrumentation including indicator sensing points:

a. End of Line Indicator Lights

TERMINAL OBJECTIVE

4.00 Given necessary procedures or other technical documents and system conditions, **DETERMINE** the operator actions required for normal and abnormal operation of the Heat Trace System including problem recognition.

ENABLING LEARNING OBJECTIVES

4.01 **IDENTIFY** the key performance indicators used to verify correct operation of the following Heat Trace System components:

a. Thermostats
b. Heat Trace Cable

4.02 Given applicable procedures and plant conditions, **DETERMINE** the actions necessary to perform the following Heat Trace System operations:

a. Placing Heat Trace Load Center in service

b. Placing Heat Trace Panel “B” and “C” in service

c. Placing Heat Trace Panel “A” and “D” in service

SYSTEM OVERVIEW

Safety

To minimize the danger of fire from sustained electrical arcing when the heating cable is damaged or misaligned, a Ground Fault Circuit Interrupter (GFCI) device is used. The GFCI is an integral part of each Heat Trace panel circuit breaker. Because low level arcing caused by ground faults may not be stopped by conventional circuit breakers, the GFCI is set to trip at 30 milliamps of ground-fault current. These breakers are not designed to provide personnel protection. Personnel protection devices, called ground-fault interrupters (GFIs) are designed to trip at 5 milliamps of ground-fault current. Damaged heat trace cables can cause shorting of the bus wires leading to arcing or overheating. Care should be exercised when handling heat trace cable to avoid damage. Precautions are taken to avoid the production of an arc in a combustible atmosphere. Heat Trace System components are designed for hazardous and ordinary area applications. Components designed for ordinary area applications should not be substituted in hazardous locations.

1.03	**EXPLAIN the consequences of a failure of the Heat Trace System to fulfill its intended purpose, including the effects on other systems or components, overall plant operation, and safety.**

Introduction

Heat tracing at CIF is widely used because most of the equipment is outside a controlled temperature environment. The function of the Heat Trace System is to counteract the heat lost from process equipment and piping through its insulation. A Heat Tracing system is a group of process equipment and piping which is heat traced and controlled in a logical and economical manner. There are many reasons for making up the heat loss of a system. With any heat loss, there is a corresponding drop in temperature. In many cases a drop in temperature brings about unacceptable consequences. These could be freezing of water in cooling lines, steam or condensate return lines, compressed air lines, fire protection lines, storage tanks, valves, etc. A drop in temperature of process fluids could result in process precipitation, unacceptable viscosity increase or solidification of the product in the lines. Freezing of process fluids within piping and valves can cause rupture of those components. A break in system boundary has the potential to release hazardous waste to the environment and contamination of personnel. Instrumentation allowed to freeze not only affects the operation and indication of the instrument but also jeopardizes associated interlocks, control functions or alarms generated by the instrument. For example, a flow control valve may operate in response to a signal generated as a result of freezing in an instrument or detector. This action may push the system components or related systems to the extremes of operating limits. Built in safeguards and interlocks are designed to operate based on the assumption that instrumentation is calibrated and functioning properly. Reliability of the incineration process is necessary for safe operation preventing equipment and personnel injury.

SYSTEM PURPOSE

1.01	**STATE the purpose of the CIF Heat Trace System.**
1.02	**Briefly DESCRIBE how the Heat Trace System accomplishes its intended purpose.**

Heat Trace System Purpose

The Heat Trace Sytem has the following purposes at CIF:

- Prevents pipes, safety showers, eye wash stations, and tanks contents from freezing
- Raise the dew point of gas samples
- Maintains process temperatures

The Heat Trace System, a sub-system of the Electrical Distribution System, controls and distributes electrical power to the heat trace circuits. The Heat Trace system accomplishes the above purposes by converting electrical energy into heat energy within the heat trace cable. Placing the heat trace cable directly against the component allows the heat energy in the cable to be transferred to the component. Moisture developing in gas lines can collect in solenoid valves and interfere with their proper operation. Heat trace is used to keep sample lines warm to prevent moisture formation. To meet acceptable viscosity conditions of process fluids, low temperature alarms are installed in some liquid waste lines to inform operators to energize heat trace equipment.

DESCRIPTION AND FLOWPATH

2.01	**DESCRIBE the physical layout of the Heat Trace System components including the general location, and functional relationship for each of the following major components:** **a. Disconnect Switches** **b. Transformers** **c. Thermostats** **d. Heat Trace Panels** **e. Heat Tracing**
2.02	**DESCRIBE the Heat Trace System arrangement to include a drawing showing the following system components and interfaces with other systems:** **a. Disconnect Switches** **b. Transformers** **c. Heat Trace Panels** **d. Motor Control Centers**

Heat Trace System Description and Flow Path

The Heat Trace System delivers electrical power to the heat trace cable where the electrical energy is converted to heat energy. The Heat Trace System is comprised of disconnect switches, transformers, power distribution panels, thermostats, heat trace cable and associated wiring, relays, connection kits and indicating lights.

Figure 1, *CIF Power Distribution Block Diagram*, illustrates the power distribution to the Heat Trace System. Electrical power at 13,800-volts is fed to the substation through a disconnect switch. The substation transformer converts the 13,800-volts to 480-volts which is then distributed through Main Bus breaker 1B. The Main Bus then distributes power through feeder breakers to the Motor Control Centers (MCC). The Heat Trace system utilizes feeder breakers 3B and 4B to provide power to MCC 3 and MCC 6 respectively. Figure 2, *Heat Trace Power One-Line Diagram*, illustrates the power distribution from the MCC to the Heat Trace Panels. Fused disconnect switches at the MCC's provide the ability to connect/disconnect heat trace power supplied by the MCC. Operating fused disconnect H-261-HTTR-DISC-6G4, for example, will connect/disconnect power to heat trace panels A & D simultaneously. The 480-volt power from fused disconnect at the MCC is wired to the heat trace transformer fused disconnects. These disconnects can connect/disconnect the associated 480-volt to 208/120-volt step-down transformer. Four of the five heat trace transformers have disconnects installed local to the transformer. The fifth transformer associated with the Heat Trace Load Center does not have a local disconnect. This transformer can be connected/disconnected by the fused disconnect located on MCC 6, and by local circuit breakers.

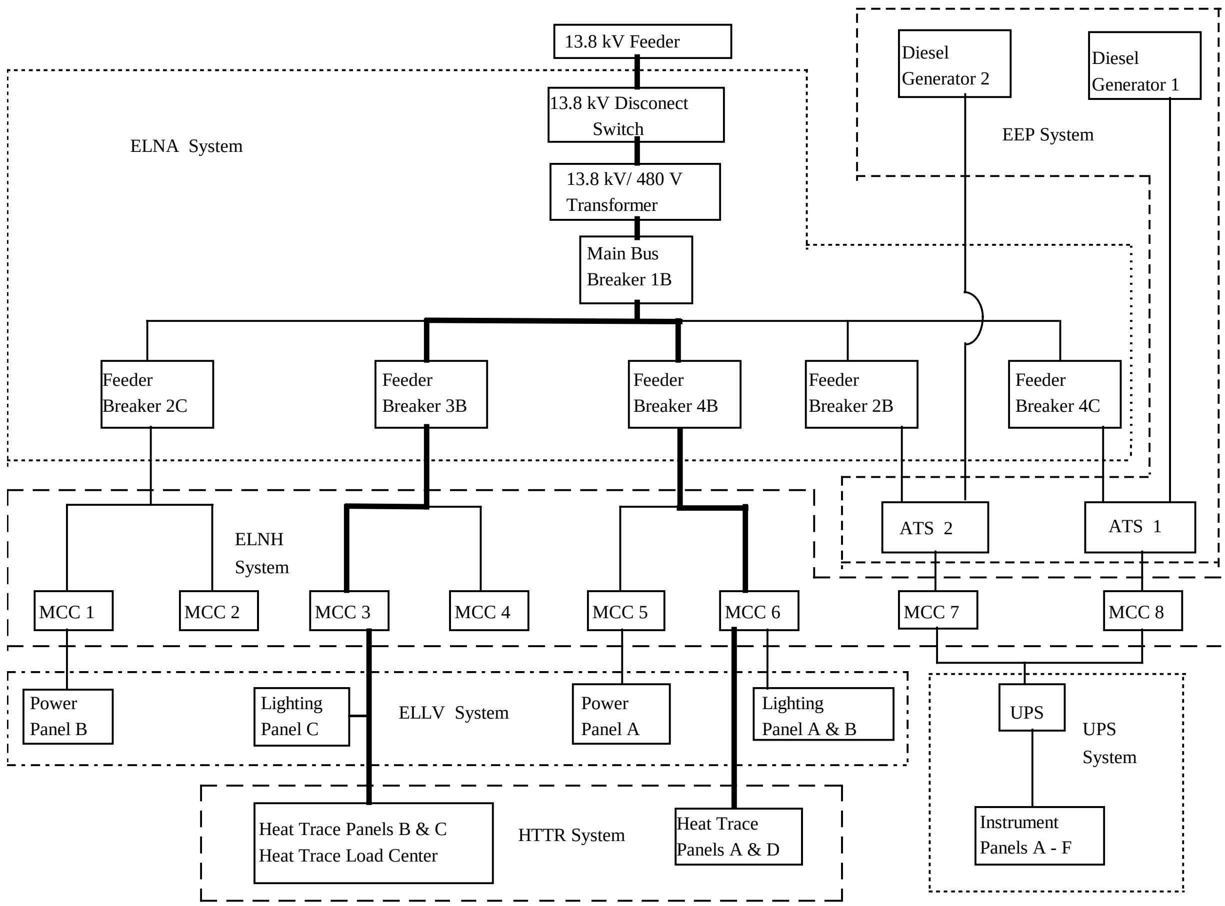


Figure 1 CIF Electrical Power Distribution Block Diagram

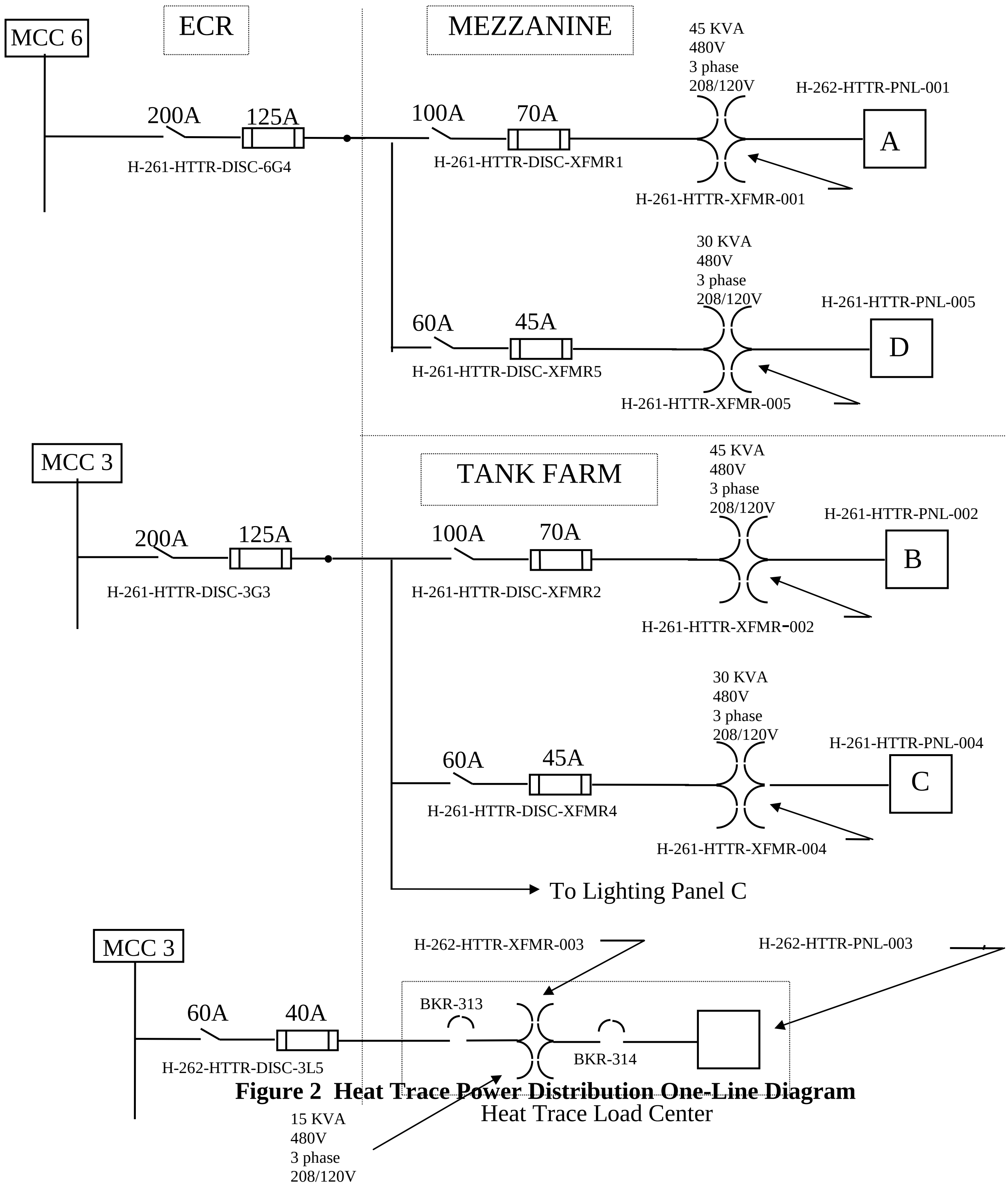


Figure 2 Heat Trace Power Distribution One-Line Diagram

MAJOR COMPONENTS

3.01	**DESCRIBE the following major components of the Heat Trace System including their functions, principles of operation, and basic construction:** **a. Disconnect Switches** **b. Transformers** **c. Thermostats** **d. Heat Trace Panels** **e. Heat Tracing**
3.02	**STATE the operational limitations for the following Heat Trace System major components:** **a. Disconnect Switches** **b. Transformers**

Heat Trace System Disconnect Switches

There are seven (7) fused disconnect switches utilized by the Heat Trace System. The switches provide circuit protection and a means to electrically isolate portions of the heat trace system. Three (3) of the disconnects are located in the Electrical Control Room (ECR), and the remaining four (4) disconnects are located adjacent to their associated transformer and heat trace panel.

The manually operated fused disconnects are used to connect/disconnect three phase power to the heat trace transformers associated with each Heat Trace Panel. The fused disconnects are operated by pulling down on an external operating handle to open, and by pushing up on the handle to close the switch. One contact is provided in each phase connected to the switch and all three contacts are operated simultaneously by the operating handle. The switch ratings given below in Table 1, *Disconnect Switches associated with the Heat Trace System*, provides the continuous current rating of the switch contacts. The switches are designed to be operated under load and have installed fuses that will blow to provide short circuit and ground fault protection.

DISCONNECT CLI	LOCATION	CONTACT/FUSE RATING	FUNCTION
H-261-HTTR-DISC-6G4	ECR @ MCC 6	200A/125A	Connect /disconnect power to Heat Trace panels B & C
H-261-HTTR-DISC-3G3	ECR @ MCC 3	200A/125A	Connect /disconnect power to Heat Trace panels A & D, and Lighting Panel C
H-261-HTTR-DISC-3L5	ECR @ MCC 3	60A/40A	Connect/disconnect power to Heat Trace Load Center
H-261-HTTR-DISC-XFMR1	OFF GAS MEZZANINE	100A/70A	Connect/disconnect power to Heat Trace Panel A power supply transformer
H-261-HTTR-DISC-XFMR2	TANK FARM	100A/70A	Connect/disconnect power to Heat Trace Panel B power supply transformer
H-261-HTTR-DISC-XFMR4	TANK FARM	60A/45A	Connect/disconnect power to Heat Trace Panel C power supply transformer
H-261-HTTR-DISC-XFMR5	OFF GAS MEZZANINE	60A/45A	Connect/disconnect power to Heat Trace Panel D power supply transformer

Table 1 Disconnect Switches associated with the Heat Trace System

Transformers

There are five (5) transformers utilized by the Heat Trace System. Each transformer is designed to step down the three phase, 480-volt supply voltage to three phase, 208/120-volts. A four wire system is created on the secondary of the transformer due to the use of a neutral wire. The loads can be connected across two lines for 208-volt operation or across one line to neutral for 120-volt operation. The 208/120-volts is connected to the Heat Trace Panels, and Heat Trace Load Center. Table 2, *Transformers associated with the Heat Trace System*, provides transformer details.

TRANSFORMER CLI	LOCATION	RATINGS	FUNCTION
H-261-HTTR-XFMR-001	OFF GAS MEZZANINE	45 KVA, 3 PHASE 4 WIRE 480-volt/208/120-volt	Steps down 480-volt supply voltage to 208/120-volts for use by Heat Trace Panel A
H-261-HTTR-XFMR-002	TANK FARM	45 KVA, 3 PHASE 4 WIRE 480-volt/208/120-volt	Steps down 480-volt supply voltage to 208/120-volts for use by Heat Trace Panel B
H-262-HTTR-XFMR-003	TANK FARM	15 KVA, 3 PHASE 4 WIRE 480-volt/208/120-volt	Steps down 480-volt supply voltage to 208/120-volts for use by the Heat Trace Load Center
H-261-HTTR-XFMR-004	TANK FARM	30 KVA, 3 PHASE 4 WIRE 480-volt/208/120-volt	Steps down 480-volt supply voltage to 208/120-volts for use by Heat Trace Panel C
H-261-HTTR-XFMR-005	OFF GAS MEZZANINE	30 KVA, 3 PHASE 4 WIRE 480-volt/208/120-volt	Steps down 480-volt supply voltage to 208/120-volts for use by Heat Trace Panel D

Table 2 Transformers Associated with the Heat Trace System

Heat Trace Panels

There are five (5) breaker panels that distribute power for heat tracing. These Heat Trace Panels have manually operated breakers that connect 208-volt or 120-volt power to the circuits. The installed breakers are Ground Fault Circuit Interrupter (GFCI) types to provide equipment protection in the event of a ground fault. The GFCI breakers provide this protection by automatically opening its contacts at a current rating lower than the overcurrent rating of the breaker. The GFCI feature will cause the breaker to trip when a ground fault current of 30ma is sensed. This lower current setting minimizes any low level arcing that may occur due to a ground fault. The breakers used in the Heat Trace Panel and the Heat Trace Load Center have overload ratings of either 15, 20, 25 or 30 amps. Each heat trace panel contains a schedule displayed on the inside of the panel door identifying the circuit number, load, breaker size, and the system serviced.

Heat Trace Panel A (H-261-HTTR-PNL-001)

Heat Trace Panel A can supply power to forty-two (42) heat trace circuits. Heat Trace Panel A is located in the Incinerator/Off Gas Area (on the mezzanine). Table 3, *Heat Trace Panel A schedule* , indicates the distribution of power from Panel A.

Table 3 Heat Trace Panel A Schedule

Heat Trace Panel B (H-261-HTTR-PNL-002)

Heat Trace Panel B can supply power to forty-two (42) heat trace circuits. Heat Trace Panel B is located in the Tank Farm Area. Table 4, *Heat Trace Panel B schedule* , indicates the distribution of power from Panel B.

Table 4 Heat Trace Panel B Schedule

Heat Trace Panel C (H-261-HTTR-PNL-004)

Heat Trace Panel C can supply power to forty-two (42) heat trace circuits. Heat Trace Panel C is located in the Tank Farm Area. Table 4, *Heat Trace Panel C schedule* , indicates the distribution of power from Panel C.

Table 5 Heat Trace Panel C Schedule

Heat Trace Panel D (H-261-HTTR-PNL-005)

Heat Trace Panel D can supply power to forty-two (42) heat trace circuits. Heat Trace Panel D is located in the Incinerator/Off Gas Area (on the mezzanine). Table 6, *Heat Trace Panel D schedule* , indicates the distribution of power from Panel D.

Table 6 Heat Trace Panel D Schedule

Heat Trace Load Center (H-262-HTTR-PNL-003)

The Heat Trace Load Center differs from the other heat trace panels. The 480-volt to 208/120-volt transformer is mounted internal to the load center and is fed with 480-volts three-phase power through an internally mounted 60A circuit breaker. The output feeds through another internally mounted 40A circuit breaker to the panel bus work. Both circuit breakers are mounted on the Heat Trace Load Center. The Heat Trace Load Center is located in the Tank Farm Area mounted at the foot of a support column for the Radioactive Organic Transfer Line.

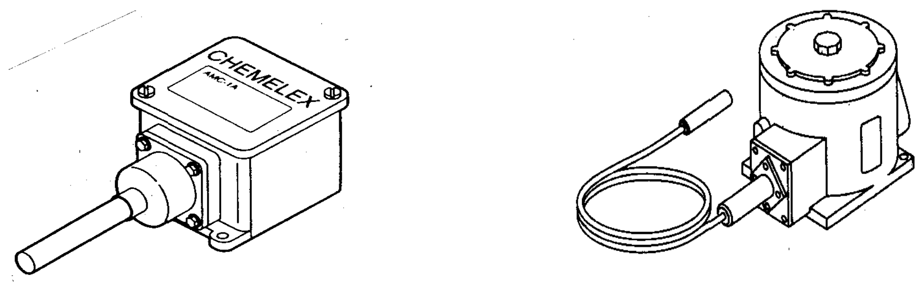
Nine of the twelve available circuits provide the heat tracing for the Radioactive Organic Waste (ROW) Transfer Line from the Defense Waste Processing Facility (DWPF). Reference 11, Drawing W836238, *SRS Bldg. 262-H Area 200H Rad. Organic Recirc.Sys. Plan,* illustrates the installation details of the Heat Trace Load Center.

In addition to the Heat Trace Panel Schedules; reference 4, 5, and 6, Drawings E-EH-H 7265-7267 *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule* provide details of circuit installation, supply breaker identification, protection type, thermostat settings, and hazardous classification, all listed by pipe line number and system. This document can be helpful to identify the power source for heat tracing applied to any CIF heat traced component, and the setpoint of the associated thermostat.

Thermostats

Thermostats are automatic devices for sensing temperature changes and operating electrical contacts in response to the temperature changes. The sensing arrangement consists of a fluid filled tube that reacts to temperature changes. Increasing temperature causes the fluid in the tube to expand and decreasing temperature causes the fluid to contract. The expansion and contraction of the fluid results in pressure changes within the tube. The force of the pressure is used to operate electrical contacts opposed by spring pressure. A lowering pressure causes the pressure of the fluid to decrease below spring pressure. The spring pressure will cause the contacts to shut. Increasing temperature will increase fluid pressure above spring pressure forcing the contacts to open. Adjustment of the spring pressure will determine the operating point of the thermostat. The electrical contacts are wired into circuits associated with the heat trace cable. Thermostats can also be designed/wired to to operate in the reverse of what is described here. That is, the contacts open on decreasing temperature and close on increasing temperature. But for heat trace applications used at CIF the circuits are required to turn on (shut contacts) when temperature lowers.

There are primarily two types of thermostat constuction. The difference in the types is related to the method of sensing temperature changes. The ambient type thermostat shown below in figure 3, *Ambient (A) and Line Sensing (B) Type Thermostats*, illustrates the short sensing probe extending from the bottom of the thermostat body. This probe responds to the surrounding or ambient temperature to cause the internal pressure change. The Line Sensing Thermostat also illustrated in figure 3, has a long length (approximately 10 feet) of stainless steel capillary tubing tipped with a larger sensing bulb. The thermostat is designed to respond to temperature changes immediately surrounding the sensing bulb. The sensing bulb can be utilized in any application such as pipe lines, valves, ducting, etc.



(A) **(B)**

Figure 3 Ambient (A), and Line Sensing (B) Type Thermostats

Figure 4 *Thermostat Sensing Bulb Installation* illustrates the proper positioning of sensing bulbs along pipe lines. The bulb is placed parallel to the pipe and taped in place. The sensor is placed on the lower half of the pipe and situated 90° from the heat trace cable on the opposite side of the pipe.

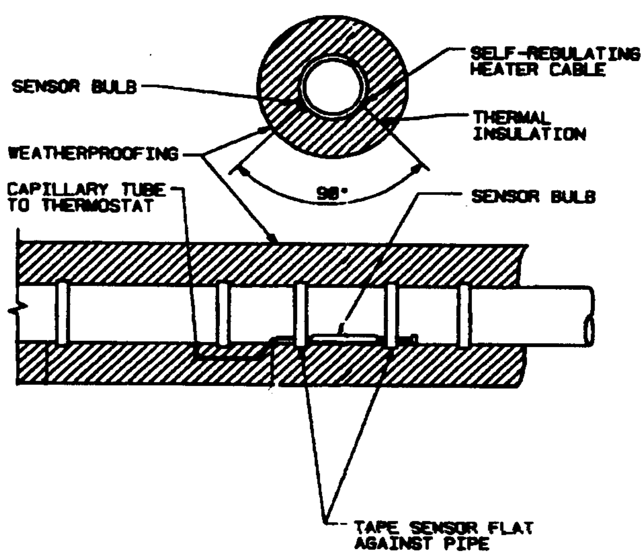


Figure 4 Thermostat Sensor Installation

The ambient thermostats associated with Heat Trace Panels A and D are located on the mezzanine in the Incinerator/Off Gas area. Ambient thermostats associated with Heat Trace Panels B and C are located behind the three sided electrical and instrumentation equipment shed in the Tank Farm area.

The classification of Heat Trace circuits at CIF are made according to their usage. Heat Trace is used either for freeze protection or temperature control of process systems. Figure 4, *120-Volt and 208-Volt Heat Trace Control Circuits*, below illustrates the use of thermostats to control Heat Trace circuits

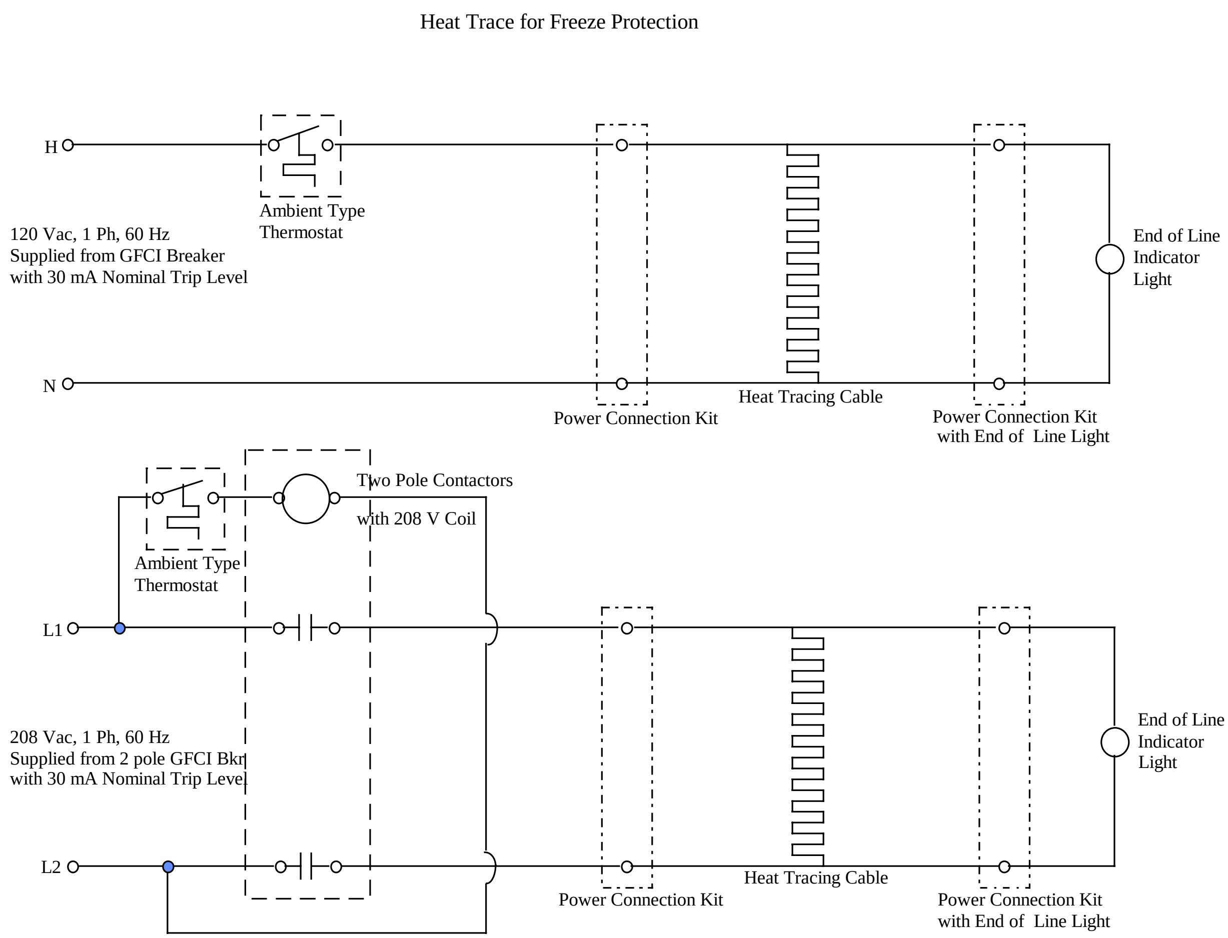


Figure 5 120-Volt and 208-Volt Heat Trace Control Circuits

The circuit shown in the top of figure 5 has a 120-volt supply which is directly controlled by the operation of the thermostat contacts. The thermostat contacts initially shown open will close when ambient temperature lowers to the thermostat setpoint. At CIF, circuits designated for freeze protection use ambient type thermostats. The ambient type thermostats are set to have a 5°F operating band. Meaning that the contacts will open 5°F above the temperature at which they closed. For example, a thermostat setting of 50°F would close its contacts at 50°F decreasing temperature and open its contacts at 55°F increasing temperature.

The closing of the thermostat contacts complete the circuit to the heat trace cable. The start of the heat trace cable run may be located several hundred feet away from the thermostat. Power from the thermostat is wired, utilizing conduit, to the heat trace cable. The start of the heat trace cable is connected to the power cable utilizing a power connection kit. The terminal box or power connection kit provides a convenient point for transition of the power cable to the heat trace cable. The Heat Trace cable can run for hundreds of feet after this connection. Another power connection kit is attached to the end of the heat trace cable. These connection kits are similiar in appearance with the exception that the connection kit at the end of the heat trace cable run has a light associated with it. This End of Line Indicator Light is electrically connected across the power to the heat trace cable. The light will be on whenever power is applied to the heat trace cable. The light would turn off in the event of a break in the power or heat trace cable, the thermostat contacts open or any circumstance that would result in loss of power to the heat trace cable. This light is the primary indication for determining proper heat trace circuit operation.

The circuit shown in the bottom of figure 5 illustrates the use of 208 volt power to operate the heat trace cable. This circuit recieves power through a GFCI circuit breaker as does the 120-volt circuit. The ambient type thermostat controls power to a relay coil which in-turn operates contacts to control power to the heat trace cable. This arrangement is necessary because of the higher power delivered to the 208 volt circuits. Since the thermostat contacts are only required to operate the relay coil, reduced wear on the thermostat contacts result which translates to longer life and less maintenance. The relay contacts are designed to handle the higher currents.

Figure 5, *Heat Trace Circuit for Safety Shower and Eye Wash Station Freeze Protection*, is an example of how line sensing thermostats can b used for temperature control. The circuit is supplied 120-volt power from the Heat Trace Panel through a GFCI breaker. Two thermostats are used to provide protection for the showers and eyewash sations. Thermostat TS-1 has a temperature setting of 60°F decreasing. The contacts will shut at this temperature and open the contacts at 70°F increasing. The second thermostat, TS-2, has normally closed contacts below 90°F, and will open its contacts at a temperature of 95°F increasing temperature. During normal operation TS-1 sensing bulb will close its contacts at 60°F decreasing temperature. This completes the circuit to the heat trace cable through the closed contacts of thermostat TS-2. The heat trace cable is now energized and the safety shower piping will begin to increase its temperature. When 70°F is reached TS-1 will open its contacts to turn off the heat trace and the cycle will repeat when temperature of the line drops back down to 60°F. Thermostat TS-2 will only operate to open its contacts if TS-1 fails to turn off at 70°F. A line temperature of 95°F will cause TS-2 contacts to open preventing excessive temperatures from building up in these lines. The line temperature will then cycle between 90 and 95°F. Temperatures up to 150°F can be reached in these lines if TS-1 failed and there were no backup.

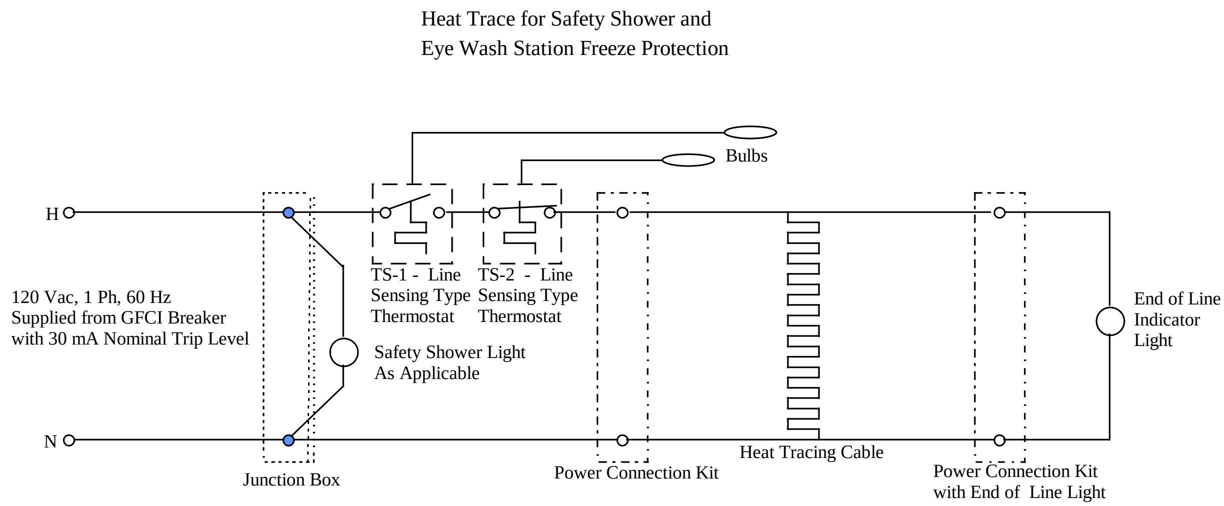


Figure 6 Heat Trace Circuit for Safety Shower and Eye Wash Station Freeze Protection

Heat Trace circuits using line sensing thermostats require the thermostat to be located nearby the pipe or component being protected.

A listing of circuits that provide freeze protection and temperature control can be found in references 4-6, Drawings E-EH-H 7265-7267, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule.*

The spare tank heat tracing is different from the rest of the facility heat tracing circuits. The spare tank heat tracing is controlled by the Tank Farm Programmable Logic Controller (PLC) Input/Output (I/O). Figure 6, *Spare Tank Heat Trace with PLC Control,* depicts the heat trace electrical schematic for the Spare Tank. When the PLC provides a contact closure output (refer to figure 6) the contactor relay coil is energized which closes its contact to energize the spare tank heat trace and energize the end of line indicator light.

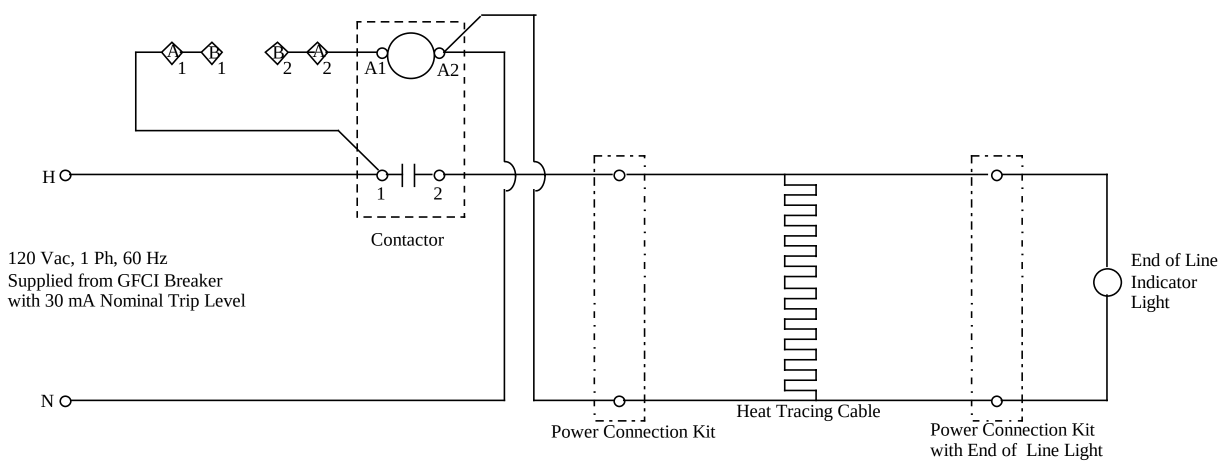


Figure 7 Spare Tank Heat Trace with PLC Control

Heat Trace Cable

The function of the heat trace cable is to convert electrical energy to heat energy. The current flowing through the resistance presented by the cable produces heat. The amount of heat generated is directly proportional to the amount of current. The heat trace cable used at CIF is called self-regulating and is illustrated in Figure 7, *Self-Regulating Heat Trace Cable*, below.

Figure 8 Self-Regulating Heat Trace Cable

Self-regulating heating cables are the latest advance in electric cable design. The self-regulating effect has many positive aspects including reduced energy usage. It is flexible and can be overlapped without burnoutmaking it easy to trace flanges, valves, instruments, etc. Self-regulating cable has the advantage that its sheath temperature is limited even under abnormal conditions. The cable consists of two parallel wires between and around which the heat generating conductive core is extruded. An insulating jacket is then extruded over the core.

The self-regulating core is in essence an infinite number of resistors which permits the cable to be cut to any length without creating cold sections. The conductive core of the cable is sensitive to temperature its immediate area. Because it is self-regulating and infinitely parallel, the output varies along the length of the cable depending on local process temperature.

The electrical resistance of the core (R_{core}) will vary directly with temperature. A drop in core temperature will lower core resistance and conversely a rise in temperature will raise core resistance. The current through the conductive core (I_{core}) will vary in accordance with the below equation.

$$I_{core} = E_{core} / R_{core}$$

The voltageE_{core}, applied to the core is a constant value of 120 or 208-volts depending on the circuit arrangement. This makes the core resistance R_{core}, the sole variable in determining the current in the core. The power or heat produced by the core is determined by the below equation.

$$P_{core} = (E_{core}) \text{ x } (I_{core})$$

Again, the voltage (E_{core}) applied to the core is a constant value of 120 or 208-volts depending on the circuit arrangement. This makes the core current I_{core}, the sole variable in determining the power or heat produced by the core. The cable is rated in units of wattage per foot and is used at CIF in wattages varying from 3 to 10 watts per foot in both 120 and 208-volt applications. Due to the design of self regulating cable the heating output can vary along the length of the cable depending entirely on the temperature of the core.

As an example, for an increasing process temperature:

the core resistance will increase:: $T_{core} \uparrow$ then... $R_{core} \uparrow$

and: $I_{core} \downarrow = E_{core} \leftrightarrow / R_{core} \uparrow$

thus: $P_{core} \downarrow = (E_{core} \leftrightarrow) \text{ x } (I_{core} \downarrow)$

Figure 8 below, *Heat Output vs Pipe Temperature for Self-Regulating Heat Trace*, illustrates how the wattage varies with change in temperature. The wattage of the cables are based on 50°F operating temperature. References 4-6, Drawings E-EH-H 7265-7267, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule,* provide the wattage rating of the cable installed on each traced pipe and the required output necessary to maintain 50°F. For proper operation the wattage rating should be higher than the required heat output at 50°F.

Figure 9 Heat Output vs Pipe Temperature for Self-Regulating Heat Trace

Heat Trace Installation

Heat trace installed on removable valves is accomplished by forming a loop in the heat trace and wrapping the loop around the valve so that sufficient slack is available to allow servicing the valve without cutting the heater cable. Figure 9, *Heat Trace Installation Over Removable Valve Bodies,* illustrates heat trace installation on valves with removable bodies.

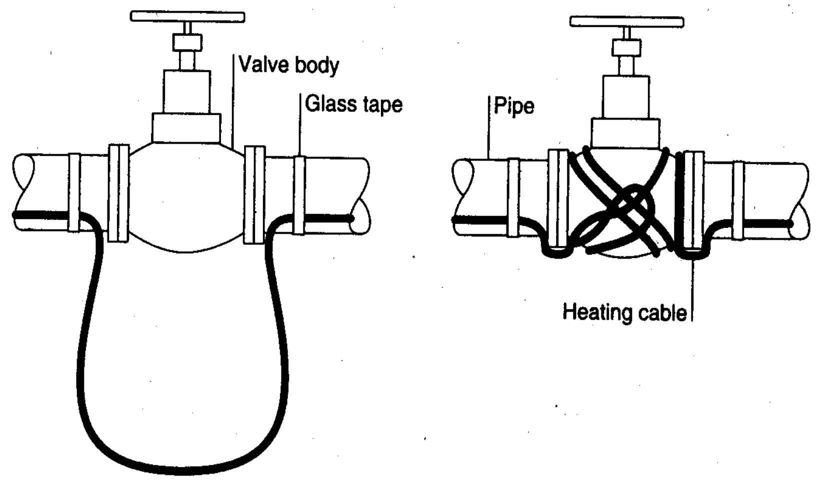


Figure 10 Heat Trace Installation Over Removable Valve Bodies

Heat trace installed on pipe elbows is normally applied to the outside (long) radius of the elbow and glass taped in place. Figure 10, *Heat Trace Installed Over Pipe Elbows,* illustrates the heat trace installation along pipe elbows.

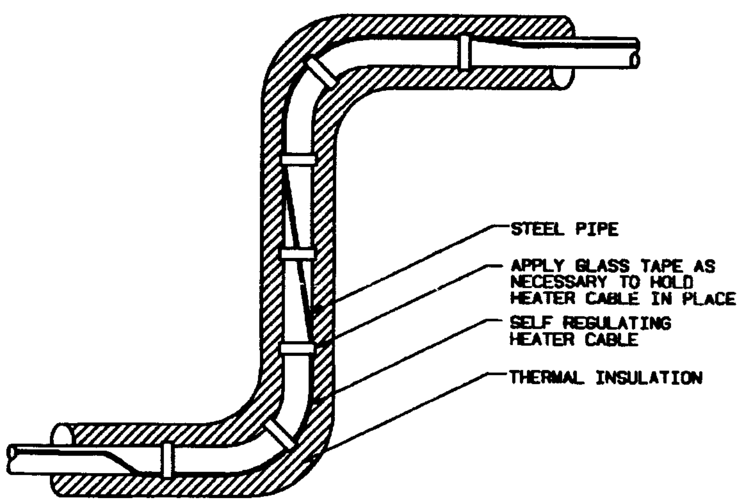


Figure 11 Heat Trace Installed Over Pipe Elbows

The position of the heat trace along horizontal pipe lengths is normally offset 45° from centerline on the lower side of the pipe. The installation of two (2) heat trace cables mounted on the same pipe requires that the heat trace be placed on opposite sides of the lower centerline 45° from the centerline. Heater Cable position is illustrated in Figure 11, *Heat Trace Installation on Horizontal Piping*.

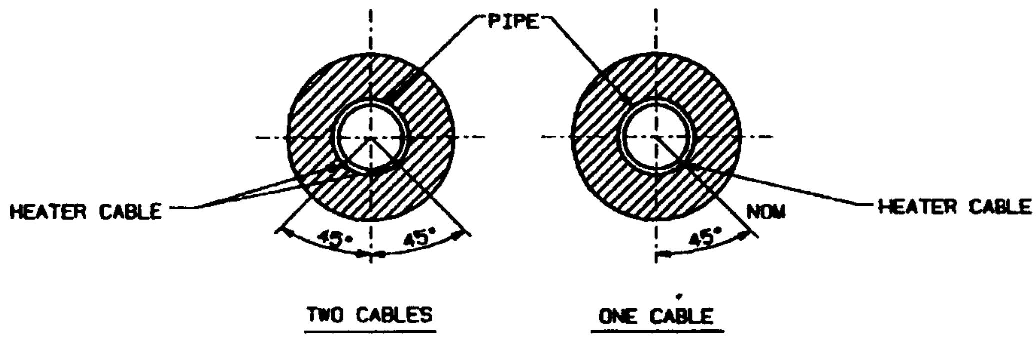


Figure 12 Heat Trace Installation on Horizontal Piping

INSTRUMENTATION

3.04	**DESCRIBE the following Heat Trace System instrumentation including indicator sensing points.** **a. End of Line Indicator Lights**
4.01	**IDENTIFY the key performance indicators used to verify correct operation of the following Heat Trace System components:** **a. Thermostats** **b. Heat Trace Cable**

End of Line Indicator lights are clear lights connected to the end of line connector kit. They act as a power ON indication that indicates the integrity of the heat trace cable circuit. The light is mounted to the side of the connection box. A connection box is a tan colored box mounted on the pipe serviced by the heat trace. The indicator light will be on whenever power is applied to the heat trace cable. The light will be off for the following conditions:

1.) Supply circuit breaker opens for any reason

2.) The circuit thermostat contacts open

3.) A break occurs in the power or heat trace cable

4.) Light bulb fails

Observing the operation of an end of line indicator light and comparing the operation to ambient temperature values can indicate proper operation of ambient thermostats. Line sensing thermostats require monitoring of loacal pipe line temperature. This procedure will verify the thermostat is functioning properly and that the heat trace cable is intact. Figure 13, illustrates a *Connection Kit with End of Line Indicator*.

Figure 13 Connection Kit with End of Line Indicator

CONTROLS, INTERLOCKS AND ALARMS

Controls

The Heat Trace System is controlled automatically by the thermostats installed in each circuit. The Spare Tank is an exception because it is controlled by DCS. The setpoints for each individual thermostat can be found in References 4-6, Drawings E-EH-H 7265-7267, *SRS Bldg. 261-H Area 200H Heat Tracing Line Schedule.*

All disconnects and GFCI circuit breakers are operated manually. The GFCI breakers will automatically trip open to isolate a circuit with a ground fault in excess of 30 ma.

The majority of the heat trace circuits have thermostats set for freeze protection at 50°F. The thermostat will automatically turn the heat trace on when temperature drops to this value and turn it off at 55°F.

Interlocks

There are no interlocks associated with the Heat Trace System.

Alarms

There are no alarms directly associated with the Heat Trace System. Some process systems however, have low temperature alarms installed to warn of lowering temperatures. The Aqueous Waste System, for example, has low temperature alarms associated with the AQW tank and AQW feed. These alarms indicate a possible failure of the associated heat trace. The low temperature alarms associated with tanks and process temperatures are related to heat trace operation providing maintenance of proper viscosity for process fluids.

SYSTEM INTERRELATIONS

2.03	**Given a description of abnormal equipment status for the Heat Trace System, EXPLAIN the significance of the condition on system operation.**

Heat tracing is applied to any line, pump, valve, or tank that contains a liquid that requires freeze protection or requires temperature control. The heat trace circuits operate independent of the individual system protected. Heat trace operation is automatically controlled by the thermostats associated with each circuit. The electrical power for operation is dependent on a constant supply from the Motor Control Cneters. A sustained loss of power from this source would jeopardize freeze protection of CIF equipment.

The installation of temporary heat trace may be necessary in instances where the installed heat trace proved to be inadequate for conditions or the lack of heat tracing prevents proper operation of the system. Temporary heat trace is made portable utilizing self-regulating heat trace and connection kits. The connection kit is equipped with a cord and plug for 120-volt operation.

The proper operation of the Heat Trace System is vital to the proper operation of gas sampling equipment. The removal of moisture from the sample lines insures reliable operation of the sampler.

INTEGRATED PLANT OPERATIONS

3.03	**Given values for key performance indicators, DETERMINE if Heat Trace System components are functioning as expected.**
4.02	**Given applicable procedures and plant conditions, DETERMINE the actions necessary to perform the following Heat Trace System operations:** **a. Placing Heat Trace Load Center in service** **b. Placing Heat Trace Panel "B" and "C" in service** **c. Placing Heat Trace Panel "A" and "D" in service**

Normal Operations

When conditions require the heat tracing to be energized, the breakers and switches associated the heat trace power must be manually placed in the ON position. The thermostats are then relied on to automatically provide freeze protection for the equipment protected. Procedure 261-SOP-HTTR-01, *Heat Tracing* (U), requires the switch lineup be performed as directed by the General Operating Procedures (GOP) or by the Shift Supervisor. The GOP requires performance of or verification that a completed copy of sections 4.2 - 4.6 of 261-SOP-HTTR-01 is in the Facility System Status File. This is done prior to process startup from cold standby to warm standby. The procedure consists of a switch line-up to provide power to the Heat Trace circuits allowing them to operate automatically. Prerequisites to Heat Trace system operation are to ensure that power from the 13.8kV/480-Volt substation is available at MCC 3 and MCC 6.

Placing Heat Trace Load Center in Service

To place the Heat Trace Load Center in service, Attachment 1 to 261-SOP-HTTR-01 is performed. The attachment goes through a breaker by breaker line-up of all breakers associated with the Heat Trace Load Center. The line-up ensures that there is power to and from the transformer associated with the Heat Trace Load Center. Furthermore the switch line-up ensures that all panel mounted breakers connected to a circuit are shut and all spare breaker are open.

Placing Heat Trace Panel B and C in Service

To place Heat Trace Panel B and C in service, the fused disconnect at MCC 3, and local transformer disconnects are closed. Additionally, Attachment 2 and 3 to 261-SOP-HTTR-01 are performed. The attachments go through a breaker by breaker line-up of all breakers associated with Heat Trace Panel B and C. The switch line-up shuts all panel mounted breakers connected to a circuit and opens all spare breakers. The lineup also ensures the main breaker for each heat trace panel is shut.

Placing Heat Trace Panel A and D in Service

To place Heat Trace Panel A and D in service, the fused disconnect at MCC 6, and local transformer disconnects are closed. Additionally, Attachment 4 and 5 to 261-SOP-HTTR-01 are performed. The attachments go through a breaker by breaker line-up of all breakers associated with Heat Trace Panel A and D. The switch line-up shuts all panel mounted breakers connected to a circuit and opens all spare breakers. The line-up also ensures the main breaker for each heat trace panel is shut.

Abnormal Operation

The operation of the heat trace system is automatic. The heat trace cable will energize and deenergize in response to temperatures sensed by the system thermostats. A failure of the thermostat, or a circuit fault can prevent the normal operation of the system. Normal operation of the Heat Trace system can only be determined by visual inspection of the end of line indicator light associated with each circuit. Since these circuits operate at various temperatures the lights will operate at different times. Observing an end of line indicator light that is out may be normal for one circuit but abnormal for another. To determine the operational characteristic of each circuit the setpoint of circuit thermostat must be known. The setpoints of the thermostats are provided on heat trace line schedules, references 4-6.

If a circuit is suspected of improper operation the following basic procedure would help in this determination. Having only a pipe line number is all that is needed to begin. Utilizing P&ID's the thermostat setpoint and circuit power supply can be determined. Each system or service has a grouping of pipe line numbers reserved for its use. The sytsem can be identified using CIF Drawing Schedule Process and Power, W830431. This drawing is posted in the control room. Once the system or service is identified it may be necessary to determine the designation assigned to the system. Table 7, *Service Designations* , is taken from drawing W830340, Symbols and Abbreviations Power, Process & Service Diag. Power & Process. These designations are used on the Heat Trace Line Schedules and the Heat Trace Panel Schedules previously discussed. The Heat Trace line schedules are sorted alphabetically by service designation and then by line number. Finding the service designation and the line number will allow you to determine the following information from the Heat Trace Line Schedule:

- Line length in feet
- Protection type and temperature setting
- Hazardous classification
- Wattage required to maintain 50°F
- Cable rating
- Power supply panel and circuit number
- Installation details drawing number

Now that you have the power supply and setpoint of the thermostat, evaluation of circuit operation can be completed. Checking power to the circuit should be the first step by visual inspection of the circuit breaker. The breaker should be closed for normal operation. Next, the operation of the circuit should be checked by monitoring the temperature and end of line indicator light. If the circuit does not respond as expected the circuit should be repaired.

Table 7 Service Designations